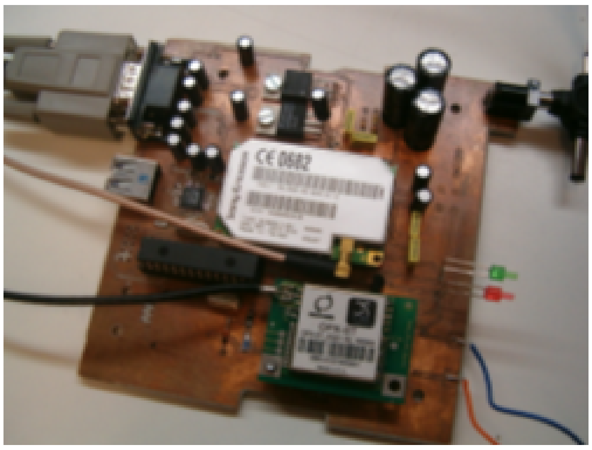

Figure 2. A GPS-GSM prototype

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Network Management for Marine Sensor Networks

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1. Introduction

Communication networks for connecting heterogeneous systems are going to play a key role in the development of future large data acquisition systems projects in marine science (some of them have already become a reality), particularly in Oceanographic Observation Systems.

In these scenarios, many technological challenges arise that can be approached either improving each of the individual network elements separately (data, sensors, communication protocols, physical layer, etc..) or managing the system as a whole. The purpose of this paper is to make a first theoretical approach to the use of network management techniques in "Marine Sensor Networks". These are already being applied in other fields in which the management of resources is a key element and in which it is necessary to provide services under QoS agreements, such as mobile telephone providers or Internet service providers.

1.1. Marine Sensor Networks

A Marine Sensor Network (MSN) is a group of Instruments and Data Acquisition Systems that, by means of a communications link, work in a cooperative way in order to obtain data from the marine environment.

For instance, cabled MSNs are an ideal way of observing the ocean in a continuous way. They are reliable for many years, offer high band width telemetry and are inexpensive to operate once installed [1].

When deployed over large sea floor areas with the purpose of obtaining long term datasets, MSNs will be a basic tool in Operational Oceanography[1]. The development of MSNs has been widely promoted by the most relevant international organisms for marine science and technology management [2][3].

Some large MSN projects have started recently, such as NEPTUNE [4], that is now in the first sea tests phase. Other projects at their first definition stage, like ESONET [5], are drawing together several marine science centers and technological enterprises from different countries.

One of the most important key items related to the development of these networks is the management of the heterogeneity: different systems and technologies are concurrent in the same network, forced to share hardware resources and exchange data.

Another important aspect of these networks is the maximum extension of the operational time range of the deployed instrumentation, in order to elongate the time data series and also to make the high costs of the network installation more profitable.

Some other projects related to NEPTUNE, such as SENSORS [6], have started recently with the objective of solving these two important aspects.

1.2. Network Management

The Network Management is defined as the group of tasks and techniques related to the planning, organization and supervision of all elements within a network, independently of their nature and location.

The main goal of the Network Management is to reach the maximum levels of availability, efficiency and effectiveness, through the global

management and control of the elements in a network.
The Network Management is based on a cycle that comprises:

- ·Obtaining information about the network elements status
- ·Global analysis of this information
- ·Decisions and actions over the network.

In a MSN scenario, obtaining information is not restricted to the physical elements of the network (instruments and the communication network itself) but is also centered in the knowledge of the marine environment (Fig. 1). The knowledge of the ocean in a MSN is a fundamental part of the information that will determine the decisions devoted to the improvement of the global efficiency of the network.

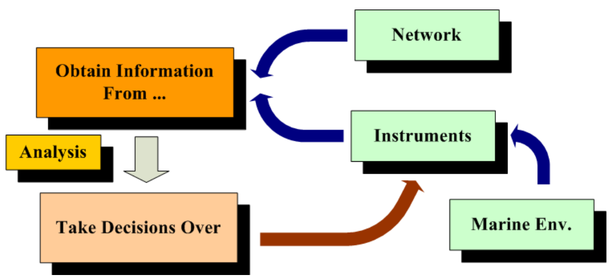

Figure 1. Management cycle for a Marine Sensor Network

2. Applicability of Network Management techniques to MSNs

2.1. Operational Time Range

In a MSN, if we don´t consider the wearing of sensors subject to the aggressive marine conditions (fouling, etc.), the instruments' operational time range is determined by the energy availability and by the data storage capacity. Because Network Management allows a deep knowledge of the state of each network element and also a global knowledge of the environment, the acquisition rate of each instrument can be adapted to the predicted variability of the measured parameters, thus extending the operational time range.

Some network technologies can provide interesting solutions, such as Mobile Agents, which have already been proposed for network management tasks [7] [8].

Mobile Agents have the ability to take decisions over their own mobility. This is an advantage when an adaptive behavior is needed or in low bandwidth networks, because their use reduces the network traffic.

An Agent visiting periodically each network node can collect information about the energy status and free storage capacity of each instrument. It can also get a general image of the environment, and thus tell each instrument its appropriate working rate.
As an example, an Agent could detect the propagation velocity of the seawater temperature in the observed area. With this knowledge, the Agent can decide to adjust data storage and transmission rates in each instrument, accordingly. This is a decentralized way to adjust the MSN performance to the environment variability, hence increasing the operational time range.

2.2. Heterogeneity

Because of deployment costs, the MSNs will be shared infrastructures. For the same reason they will be operative during several years. It is necessary to provide MSNs with easy rules in order to integrate different instruments from different manufacturers and operators, most of them not planned to be attached at the initial design phase. Instruments will not use the MSN as a mere way of obtaining energy or transmitting their data, but they will cooperate with each other. Therefore, there is a need to integrate instruments in a logical way (data structures, and communication protocols). This integration can be reached using very well defined interfaces that provide accurate specifications on how instruments can share data, and also using the permanent knowledge of where the needed data is placed (nodes and communication ports).

Network services in a MSN are defined as the collection of the data provided by any instrument, and the storage and to land transmission capabilities offered by any network node. These services and the network topology will change with the integration of new instruments. A more flexible and scalable way of integrating instruments is to use mechanisms for a dynamic detection of the communication rules imposed by each instrument, and to find out on-line the network services.

Network management is a perfect tool for the integration procedures above mentioned. Once more, advanced network technologies can provide interesting solutions to this issue. An Agent can be launched by a new instrument incorporated to the network. Then the Agent will visit every node and will collect information on where the services needed for the correct integration of the instrument are located, and how to access them. At the same time, the Agent will announce the characteristics of the newcomer to the rest of the nodes. Other plug and play and service discovery technologies, like Jini^{TM} or WebServices [9] service description language (WSDL), can be successfully implemented in a MSN, but probably lack the flexibility provided by Agents.

2.3. Fault Tolerance

Although MSN are remotely operated, they must have a low maintenance. This is because

it is quite difficult to have a physical access to the nodes in order to fix problems.
Fault tolerance and automatic recovery must be desirable features. A MSN must provide fault notification and procedures to reconstruct the data acquisition and transmission scheme when one or more components fail.
Fault tolerance can be implemented with enough redundancy at different levels (sensors and network), but network management can also be a good tool to enhance the reliability of the MSN.

It is possible to predict some faulty conditions - detecting worsening of data and sensing instrument and network performances- by a systematic analysis of both MSN nodes and acquired data. This analysis will also provide the data quality log, which is an important parameter for a correct interpretation of the data.

The global network knowledge can be used again as a parameter for taking decisions. It can be used for searching alternative data sources or communication routes, in order to maintain data consistency and avoid losses of information.

Performance checking can be included as a standard service of each instrument, and the technologies aforementioned can be used to maintain a global view of the MSN performance and react automatically against a faulty condition. Once again, the most important aspect is the ability of the management system to detect services and to obtain a global perspective.

2.4. Quality of Service

Quality of Service (QoS) in a MSN must be understood as the level of data quality. It is mandatory to know the measurements accuracy and the error rate related to any instrument, the accuracy of the references (mainly time and position also in the case of mobile instruments), and the knowledge of all the acquisition conditions that can induce errors (energy source levels, data transmission quality, environment conditions like temperature or pressure, etc.). It is also important to know how the MSN is working as a whole, if there is any faulty condition in any node that provide data to the other nodes or if the environment is changing more quickly than the storage and transmission rates.
Network management provides a good way for obtaining this QoS knowledge, and technologies that collect information from nodes in a decentralized way can be a good choice.

3.Conclusions

Network management technologies offer good solutions for dealing with the complexity, reliability, data quality and maintenance of a MSN.
New network management technologies, such as Mobile Agents and WebServices, are options that must be taken into consideration. Particularly the way to implement them, considering the MSN conditions and the necessary infrastructure to allow them to work.
Network Management policies must be included as a part of the present and future MSN projects, investigating the application of new network technologies.

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